Ethanol in Groundwater at a Northwest Terminal

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Groundwater Investigation

- In March, 1999 a 19,000-gallon release of neat ethanol occurred from an above ground storage tank
- Following the ethanol release, nine monitoring wells were installed in the fill and sampled six times between June 1999 and December 2000
- In May 2000 a sampling protocol was implemented to measure for indicators of in situ bioremediation
- In December 2000 eight additional monitoring wells were installed in the shallow fill and the deeper alluvium
- The objective of the groundwater sampling program is to delineate the ethanol plume and understand the impact of ethanol on the existing nonaqueous phase liquid (NAPL) and dissolved hydrocarbon plumes

The Cosolvent Effect

- With a sufficiently large amount of ethanol in a localized subsurface environment, gasoline and water become completely miscible with each other and merge into a single phase (Powers et al., 2001)
- Laboratory experiments demonstrate a logarithmic increase in BTEX with increasing ethanol concentrations (Heerman and Powers, 1998)
- Neat ethanol releases could result in an order of magnitude increase in BTEX concentrations (Powers et al., 2001)

Ethanol Biodegradation and the Impact on BTEX

- Ethanol can be degraded in both aerobic and anaerobic environments at a faster rate than other gasoline constituents
- Ethanol concentrations exceeding 40,000 mg/L in microcosm experiments were toxic to the microorganisms, as shown by a complete lack of oxygen consumption (Hunt et al., 1997)
- Ethanol will most likely be preferentially utilized over all the BTEX compounds under aerobic and anaerobic conditions
- Ethanol constitutes a significant demand on oxygen (and other electron acceptors) and is likely to cause the depletion of electron acceptors for BTEX degradation
 - this is particularly important for benzene because it degrades slowly under anaerobic conditions

Effect of Ethanol on BTEX Biodegradation

- da Silva et al. (2001) conducted microcosm experiments to study aerobic, denitrifying, iron-reducing, sulfate-reducing, and methanogenic conditions
- Aquifer materials from the Northwest Terminal were included in these experiments
 - ethanol retarded toluene degradation under aerobic, sulfatereducing, and iron-reducing conditions
 - ethanol enhanced toluene degradation under denitrifying conditions

Northwest Terminal History and Setting

- The terminal began operations in 1911, distributing and blending a variety of petroleum products
- The area was once predominated by lakes and sloughs, filled with dredge materials from a nearby river
- Two other terminals border the site to the north and south; more than 100 borings and monitoring wells have been completed at the three terminals

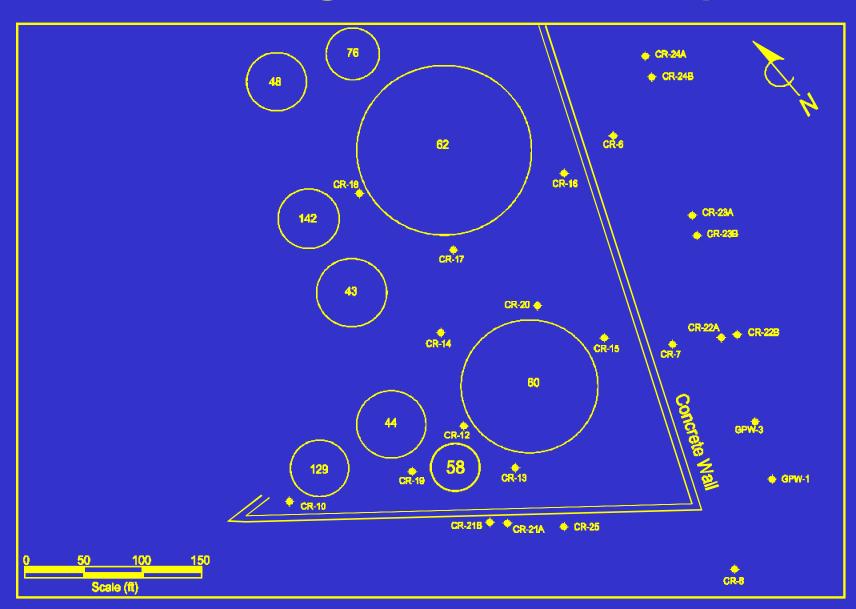
Site Geology

- Fill material of gravel, silt, and sand has been deposited over most of the site, varying in thickness from nonexistent to greater than 30 feet
- Fill is underlain by Holocene alluvial deposits of clay, silt, and sand
- In six borings at the terminal, the alluvium occurred to a depth of approximately 50 feet below grade; based on these borings, basaltic material is present at approximately 50 feet below grade

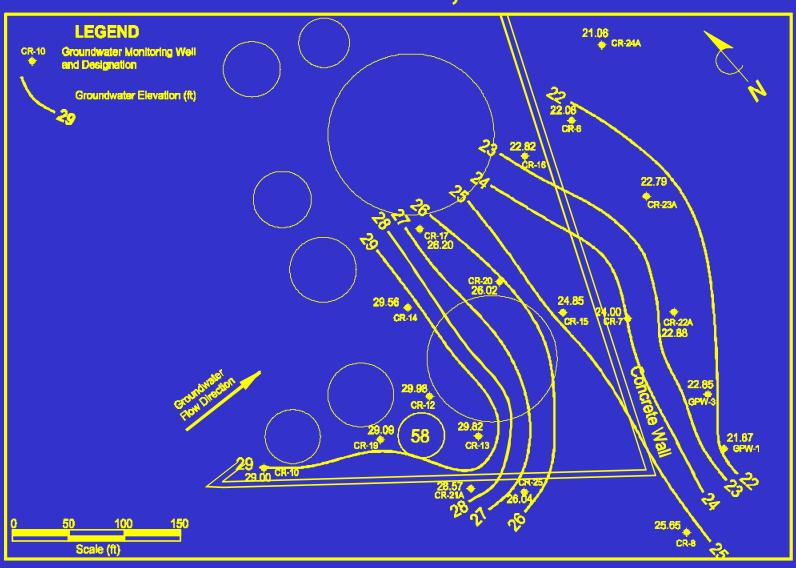
Site Hydrogeology

- The fill and alluvium are hydraulically connected; the units discharge to a river, approximately 1500 feet east of the ethanol release
- The fill is the primary zone for the occurrence of hydrocarbons
- Depth to groundwater varies from 2 to 15 feet below grade
- Groundwater velocity within the upper sandy fill is approximately 300 to 400 feet per year

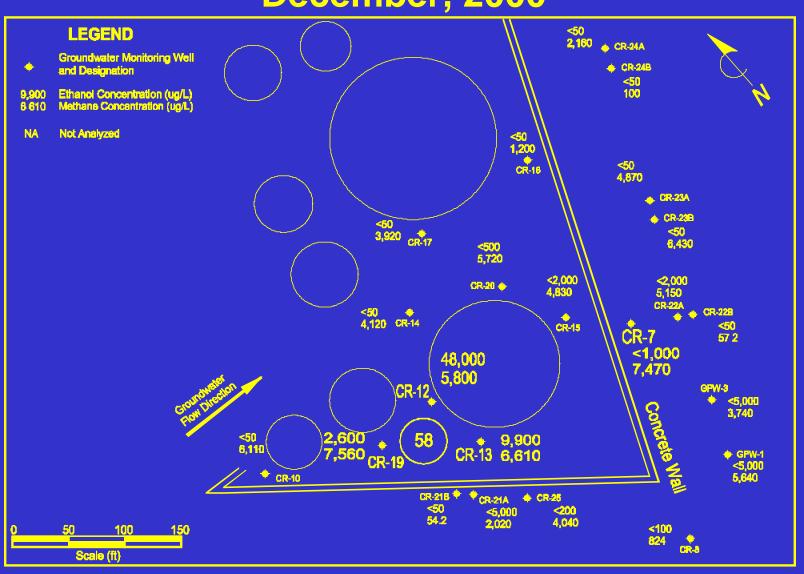
Monitoring Well Location Map



Groundwater Elevations December, 2000



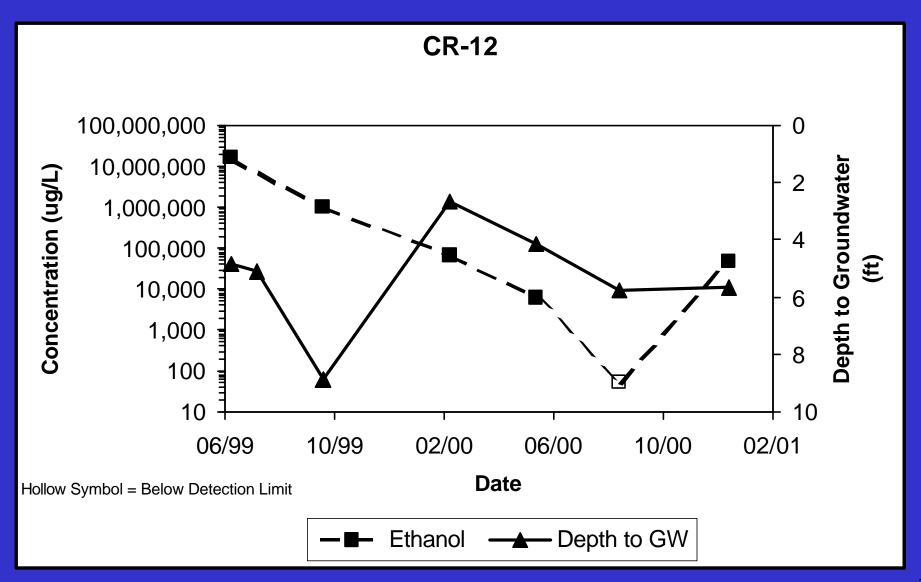
Ethanol and Methane Concentrations December, 2000



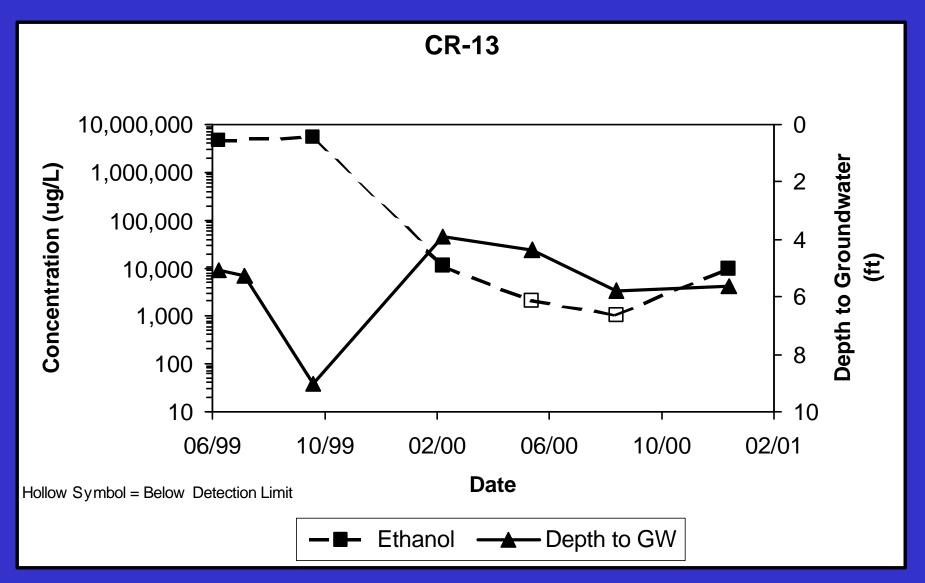
Groundwater Investigation Results

- Ethanol migrated approximately 250 feet (CR-16) between March and September 1999, consistent with groundwater velocity estimates
- Ethanol concentrations in two monitoring wells near the release have declined significantly over 18 months (CR-12 and CR-13)
- Ethanol appears to enhance the thickness of NAPL in two monitoring wells (CR-19 and CR-15)
- Cosolvent effects of ethanol are suggested by benzene concentrations increasing by a factor of 10 or more in one monitoring well (CR-7)
- The presence of ethanol has created a strongly anaerobic groundwater system, demonstrated by low dissolved oxygen, depleted nitrate and sulfate, and high methane concentrations

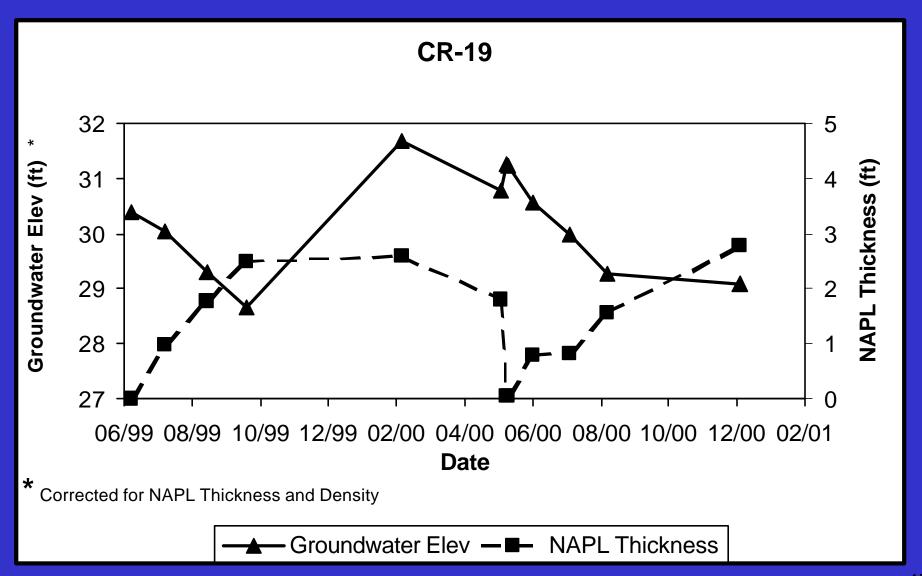
Ethanol and Depth to Groundwater versus Time



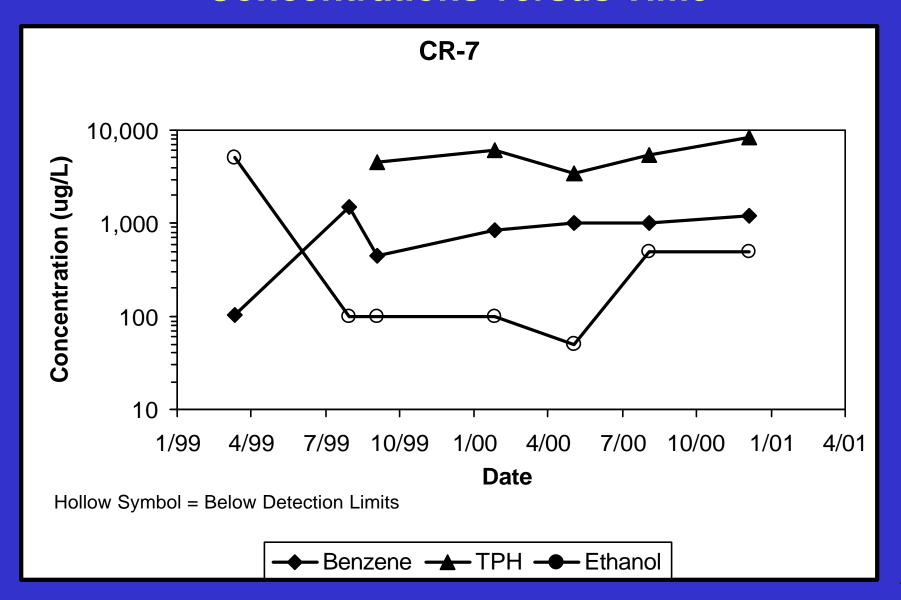
Ethanol and Depth to Groundwater versus Time



NAPL Thickness and Groundwater Elevation versus Time



Benzene, TPH & Ethanol Concentrations versus Time



Summary

- 17 new monitoring wells were installed over an 18-month period to delineate the ethanol plume that resulted from a 19,000-gallon release of neat ethanol
- The presence of ethanol in the subsurface has affected petroleum hydrocarbons in both the NAPL and dissolved phases
- There is evidence for ethanol biodegradation under methanogenic conditions, demonstrated by declining ethanol concentrations and high methane concentrations in the footprint of the ethanol plume
- Ethanol concentrations at UST release sites (10% ethanol) are not likely to be sufficiently high to cause cosolvent effects for BTEX

References

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